Executive Summary

Background and Objectives: The discharge of ships' ballast water is probably the greatest single source of new introductions into aquatic habitats (Carlton & Geller 1993; Cohen & Carlton 1995; Cohen 1998). Recent ballast introductions in the Bay/Delta system include the Asian clam, which has transformed upper bay trophic dynamics with possible impacts on endangered and sport fish (Kimmerer *et al.* 1994), and may be acting as a contaminant pathway delivering selenium at toxic concentrations to bottom-feeding birds and fish (Thompson & Luoma 1999); several species of Asian copepods and mysid shrimp, which may also be altering food availability to endangered and sport fish in the upper Bay and Delta (Meng & Orsi 1991; Orsi 1995); and possibly the Chinese mitten crab, which has invaded and interfered with state and federal water diversion facilities, power plants and wastewater treatment plants, may reduce the stability of levees as well as river banks, ditches and berms, and may compete with crayfish that support a commercial fishery in the Delta (Cohen & Carlton 1997). Judging from introductions that have occurred elsewhere, future ballast water introductions in the Bay and Delta could have even more severe impacts on water delivery systems, endangered fish, commercial fisheries and even on human health.

Despite the importance of this invasion vector, the ballast water arriving in the Bay and Delta has never been sampled. We thus have no direct information on the types and numbers of exotic ballast water organisms being introduced into the Bay/Delta ecosystem or on the physical and chemical characteristics of this ballast water, and little information on the sources and volumes of ballast water being discharged. Such information is urgently needed for the development, implementation and monitoring of ballast water treatment and management efforts; for the development of regulatory policy; and for scientific efforts to understand the factors that contribute to the rate and extent of invasion in different ecosystems.

This project will compile and analyze shipping data and sample and analyze ballast water arriving in the Bay/Delta region in order to develop:

- Data on the types and concentrations of organisms arriving from different source regions, which are needed to conduct relative risk assessments and to develop risk assessment-based ballast water management systems.
- Data on the types and concentrations of organisms and on the physical or chemical parameters of exchanged and unexchanged ballast water, which are needed to assess the effectiveness of exchange and to develop and assess methods to monitor exchange.
- Data on the types and sizes of organisms and on the physical or chemical characteristics of ballast water arriving at Bay/Delta ports, which are needed to develop and assess treatment approaches.
- Data on the types organisms and on chemical or microbial contaminants in ballast water that may pose environmental or public health risks, which are needed to determine the urgency and appropriate scope of regulatory action on ballast water.
- Data on the types and concentrations of organisms arriving in ballast water, which are needed to conduct comparative analyses between ecosystems and over time to assess which factors control the rate and extent of invasion.

Methods: This 2-year project will: acquire and analyze data on shipping patterns; sample and analyze the biota and the chemical and physical parameters of ballast water and sediments arriving in the Bay/Delta system; and test this data for correlations over time and between estuaries for correlations between ballast water biota, ballast water source regions, and the establishment of non-indigenous species. Data on ship arrivals (e. g. ship type, size, last port-of-call) from the San Francisco Marine Exchange and other sources will be analyzed for ballast water volumes and sources, and changes and trends over time. Ballast sampling will be conducted by vertical plankton tows or pump sampling, for a range of vessel types, sizes and source regions. Sediments, macrofauna and other seawater system components will be sampled as opportunity permits. Whole water samples will be collected for physical, chemical and microbial analysis.

Biologic samples will be examined initially to determine if the plankton is alive and, if funding for this component is available, subsamples will be taken for culturing larval zooplankton. The remaining sample will be fixed for later sorting, identification to lowest possible taxon and enumeration.

Location: The laboratory and analytical work will be conducted at SFSU's Romberg Tiburon Center in Marin County and the San Francisco Estuary Institute in Contra Costa County, with supplemental laboratory work at CDFG/IEP in San Joaquin County and USGS in San Mateo County. Ships will be sampled at all Bay/Delta commercial ports, which are located in Sacramento, San Joaquin, Solano, Contra Costa, Alameda, San Mateo and San Francisco counties.

Cost: The request to CALFED is $375,905 over 2 years. Cash and in-kind contributions, primarily from the San Francisco Bay RWQCB for water quality analysis, are about $50,0000. An additional $171,000 is requested from National Sea Grant for a separable component involving the culturing and further identification of larval zooplankton.

Applicant Qualifications: Project Leader **Andrew Cohen** has conducted extensive research on nonindigenous species and transport vectors in the Bay/Delta Estuary and other west coast estuaries, including research on the rate of invasions (published in Science) and ballast water in the Estuary. He has organized and led teams of taxonomists and ecologists in Rapid Assessment Surveys for nonindigenous species in the Bay/Delta Estuary and Puget Sound, and was recently awarded a Pew Fellowship in Marine Conservation to investigate biological invasions in tropical marine ecosystems. Project co-leader **Wim Kimmerer** has conducted research on zooplankton ecology and computer modeling on such topics as the influence of predation on community structure, population dynamics of zooplankton and fish, and the interaction of plankton with their physical environment, and has published several papers on the influence of introduced species on the Bay/Delta ecosystem. He is Chair of the Interagency Ecological Program's Estuarine Ecology Team. Project Co-leader **Steven Moore** is an Associate Engineer with the Regional Water Quality Control Board, with experience in wetlands permitting, watershed monitoring and assessment, NPDES permitting and compliance, total maximum daily load (TMDL) development and implementation, and toxic pollutant control. He is currently working on the development of a TMDL for nonindigenous species in the Estuary. Project collaborators identified to date bring additional expertise in ballast water sampling, and zooplankton and protozoan taxonomy.

Local Support/Coordination: Participants in ballast water treatment studies, including the Port of Oakland, San Francisco Oceanside Laboratory and Southeast Wastewater Treatment Plant, Central Contra Costa Sanitary District, Contra Costa Water District, SWRCB and San Francisco Bay RWQCB either have been or will be notified of this study, and will have an opportunity to review the methods and results. All of the ports and many of the terminals in the Bay/Delta region will be contacted for this study, and will similarly have an opportunity to review methods and results. The Center for Marine Conservation and the San Francisco BayKeeper are aware of the proposed project and strongly support it. The Contra Costa County Board of Supervisors and Planning Department, the Delta Protection Commission and the Bay Conservation and Development Commission have been advised of the project. We anticipate that researchers or students from several institutions may become involved in this study in one way or another.

Compatibility with CALFED objectives: An ERP "Stage 1 Expectation" is that "baseline monitoring of the organisms released in ballast water should be immediately initiated so we can assess progress and monitor compliance" (Vol. I, p. 464). Several targets, actions and objectives in the ERP and Strategic Plan call for stopping the discharge of exotic organisms in ballast water into the Estuary, recognizing that the introduction of new species greatly increases the expense and difficulty of restoring the estuary, and that a new invasion can destroy the value of a restoration project (Vol. I, p. 464); and that the elimination of additional species introductions is crucial to the ultimate success of the ERP (Vol. I, p. 462, citing the Strategic Plan).